Tanta University - Faculty of Engineering
Electrical Power and Machines Engineering Department

Mid-term Exam

Second Year: Electrical Power and Machines Engineering **Time: 1 hour**
Second Term: April, 2017 **Date: 1 April, 2017**
Course Title : Electric Machines (1) **Code: EPM2208**

Question one

The following are some design particulars of a 375 rpm, d.c. compound generator with simple lap winding. (*Help: please note that you don't need all the given data*)

- Slot pitch=0.0308
- Rotor diameter=1.098 m
- Resistivity of the conductors $= 2 \times 10^{-8}$ ohm.m
- Iron stacking factor=0.9
- Area of armature conductors $= 30.3 \times 10^{-6}\ m^2$
- Tooth height $= 0.047\ m$
- Armature axial length $= 0.3\ m$
- Height of each shunt field coil $= 0.16\ m$
- Conductors per slot = 8
- Yoke depth $= 0.1\ m$
- Number of poles = 8
- Slot width $= 0.012\ m$
- Core depth $= 0.138\ m$
- Specific electric loading $= 35000\ Ac/m$
- Main flux per pole $= 91.3\ mWb$
- pole arc/pole pitch = 0.70

Determine:

[a] The flux density at 1/3 of the slot height measured from its root, in Tesla

[b] Rated power of the generator

Question two [20 Marks]

[a] **Explain** (with figures and equations if exist) the following items: Commutation, magnetic poles, fractional-pitch coil, progressive winding, base speed, plex of an armature winding. [6 Marks]

[b] For a DC machine with a simple rotating loop between curved pole faces connected to a battery and a resistor through a switch. The resistor shown models the total resistance of the battery and the wire in the machine. The physical dimensions and characteristics of this machine are $r = 0.5\ m$, $l = 1\ m$, $R = 0.3\ \Omega$, $B = 0.25\ T$, $V_B = 120\ V$. **Draw** the circuit of this machine then: [1 Mark]

i. **What** happens when the switch is closed? [1 Mark]

ii. **What** is the machine's maximum starting current? **What** is its steady-state angular velocity at no load? [2 Marks]

iii. Suppose a load is attached to the loop, and the resulting load torque is 10 Nm. **What** would the new steady-state speed be? **How** much power is supplied to the shaft of the machine? **How** much power is being supplied by the battery? **Is** this machine a motor or a generator? [2 Marks]

[c] **Explain** the method of "*compensating windings*' to cancel the armature reaction. The answer has to include: (i) the configuration of the machine to show the effect of compensating windings (ii) the flux and magnetomotive forces without and with compensating windings. [5 Marks]

[d] **Explain** (with aid of figures and equations) how the speed of a shunt DC motor is controlled by changing the armature voltage. [3 Marks]

With Best Regards

Prof. Dr. Ahmed Shobair, Dr. Abdelsalam Ahmed

$n = 375$ rpm d.c. Compound gen., simple lap

$\tau_s = 0.0308$	$Z_s = 8$
$D = 1.098$ m	$d_y = 0.1$ m
$\rho = 2 * 10^{-8}$ ohm.m	$2p = 8$
$k_s = 0.9$	$b_s = 0.012$ m
$a_e = 30.3 * 10^{-6}$ m^2	$d_c = 0.138$ m
$h_s = 0.047$ m	$\overline{AC} = 35000$ Ac/m
$L = 0.3$ m	$\Phi = 91.3 * 10^{-3}$ wb
$h_e = 0.16$ m	$\alpha = 0.7$

Req: [a] $B_{1/3}$

[b] P_ℓ

Solution: [a] $B_{1/3} = \dfrac{\Phi}{k_f \frac{S}{2p} b_{t\,eff} L_i}$

$k_f \simeq \alpha = 0.7$

$\tau_s = \dfrac{\pi D}{S}$; $S = \dfrac{\pi D}{\tau_s} = \dfrac{\pi * 1.098}{0.0308} = 111.9957$

$\simeq 112$ slot

$L_i = L * k_s = 0.3 * 0.9 = 0.27$ m

$$b_{t\,eff} = \frac{\pi\left(D - \frac{4}{3}h_s\right)}{S} - b_s$$

$$= \frac{\pi\left(1.098 - \frac{4}{3} * 0.047\right)}{112} - 0.012 = 0.017 \text{ m}$$

$$\therefore B_{1/3} = \frac{91.3 * 10^{-3}}{0.7 * \frac{112}{8} * 0.017 * 0.27} = \boxed{2.0297 \text{ T}}$$

#

[b] $P_d\,(kW) = C_o D^2 L n$

$$C_o = 0.164 * B_{av} * \overline{AC} * 10^{-3}$$

$$= 0.164 * \frac{\Phi}{\tau_p L} * \overline{AC} * 10^{-3}$$

$$= 0.164 * \frac{\Phi}{\left(\frac{\pi D}{2p}\right) L} * \overline{AC} * 10^{-3}$$

$$= 0.164 * \frac{91.3 * 10^{-3}}{\left(\frac{\pi * 1.098}{8}\right) * 0.3} * 35000 * 10^{-3}$$

$$= 4.051344\cancel{41}$$

$$P_d = 4.0513 * (1.098)^2 * 0.3 * 375$$

$$= \boxed{549.4796 \ kW} \ \#$$

Another Solution for [b]:

$$E_A = \frac{2P}{2a} Z \Phi \frac{n}{60} \; ; \quad Z = S\, Z_s = 112 * 8 = 896$$

for simplex Lap, $2a = 2p = 8$

$$E_A = \frac{8}{8} * 896 * 91.3 * 10^{-3} * \frac{375}{60} = 511.28\ V$$

$$\overline{AC} = \frac{I_c Z}{\pi D} = 35000; \quad \frac{I_c * 896}{\pi * 1.098} = 35000$$

$$I_c = 134.7448\ A$$

$$I_A = I_c * a = 134.7448 * 8 = 1077.9584\ A$$

$$P_d\,(kW) = E_A I_A * 10^{-3}$$

$$= 511.28 * 1077.9584 * 10^{-3}$$

$$= \boxed{551.1385\ kW} \ \#$$

The result is the same, the small difference is due to rounding errors.

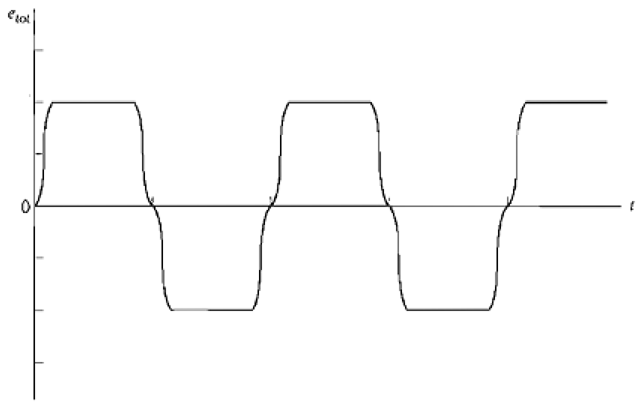
Q2:

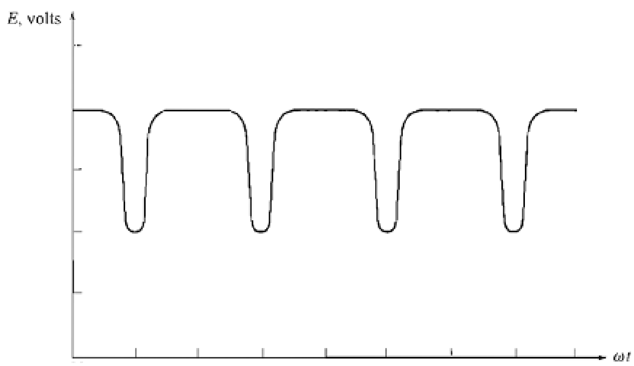
[a]:

Commutation:

Commutation is the process of converting the ac voltages and currents in the rotor of a dc machine to dc voltages and currents at its terminals.

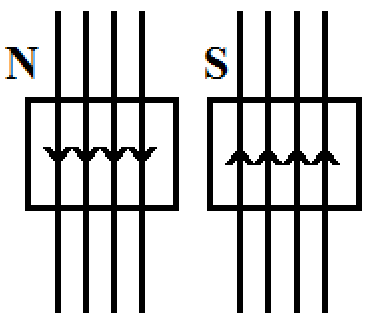
Commutation is the process of switching the loop connections on the rotor of a dc machine just as the voltage in the loop switches polarity, in order to maintain an essentially constant dc output voltage.





Magnetic Poles:

They're formed as a result of the current that flows through the rotating armature conductors when they cut the magnetic field produced by the physical poles on the stator. They produce a separate pole flux that opposes the initial flux from the stator physical poles.



Armature Conductors

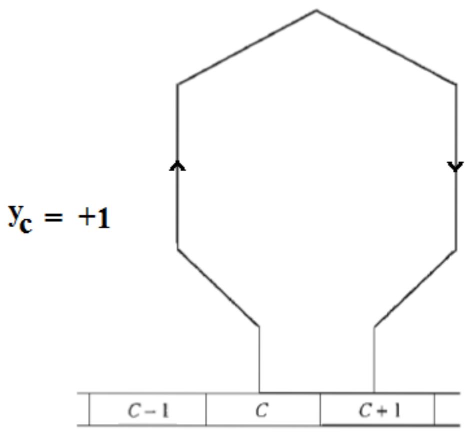
Fractional-Pitch Coil:

Sometimes a coil is built that spans less than 180 electrical degrees. Such a coil is called a *fractional-pitch coil*, and a rotor winding wound with fractional-pitch coils is called a *chorded winding*. The amount of chording in a winding is described by a *pitch factor p*, which is defined by the equation

$$\boxed{p = \frac{\text{electrical angle of coil}}{180°} \times 100\%}$$

Progressive Winding:

If the end of a coil (or a set number of coils, for wave construction) is connected to a commutator segment ahead of the one its beginning is connected to, the winding is called a *progressive winding*



Plex of an Armature Winding:

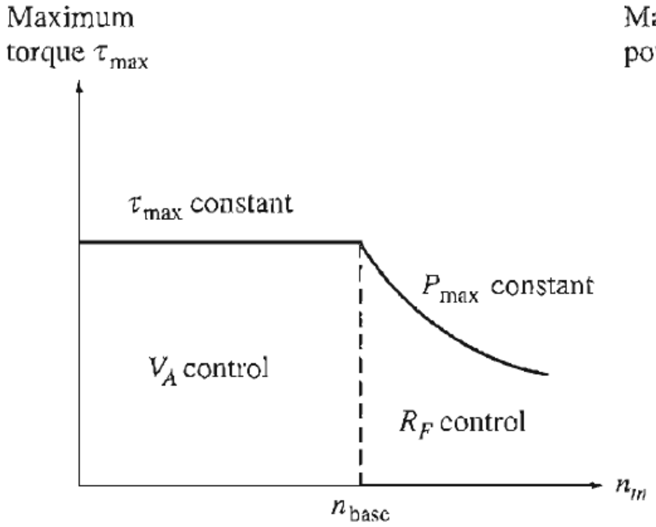
Number of independent sets of winding wound on the rotor. Or the number of complete and closed windings wound on the rotor.

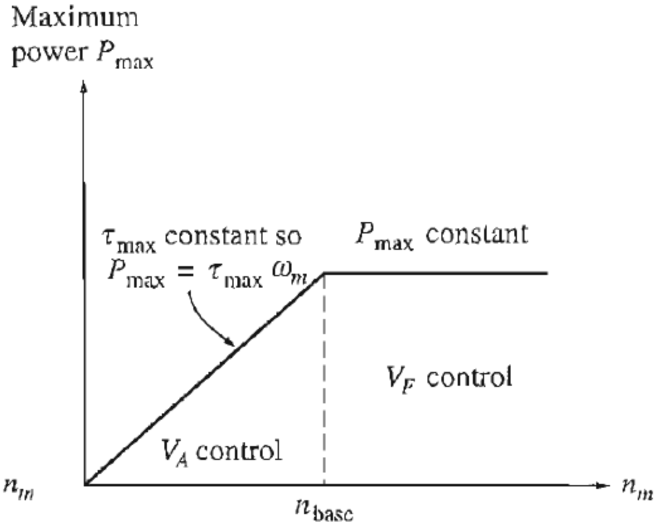
A *simplex* rotor winding is a single, complete, closed winding wound on a rotor. A *duplex* rotor winding is a rotor with *two complete and independent sets* of rotor windings. If a rotor has a duplex winding, then each of the windings will be associated with every other commutator segment: One winding will be connected to segments 1, 3, 5, etc., and the other winding will be connected to segments 2, 4, 6, etc. Similarly, a *triplex* winding will have three complete and independent sets of windings, each winding connected to every third commutator segment on the rotor. Collectively, all armatures with more than one set of windings are said to have *multiplex windings*.

Base Speed:

If the motor is operating at its rated voltage, field current, and power, it will be turning at base speed. Armature voltage control can control the speed of the motor for speeds below base speed but not for speeds above base speed. To achieve a speed faster than base speed by armature voltage control would require excessive armature voltage, possibly damaging the armature circuit.

These two techniques of speed control are obviously complementary. Armature voltage control works well for speeds below base speed, and field resistance or field current control works well for speeds above base speed.



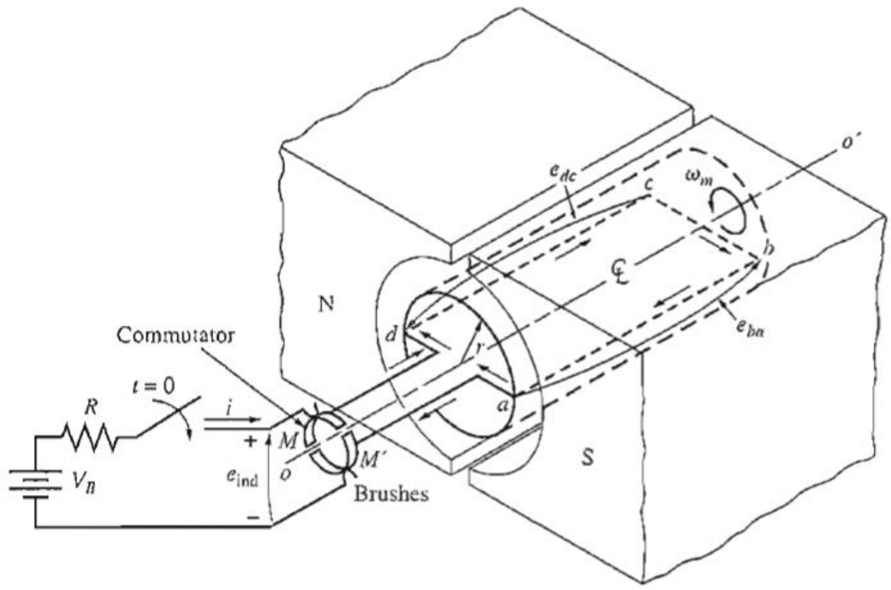


---

[b]

Solved example 7-1 in reference, page 413 to 415.

Drawing:



Solution

(a) When the switch in Figure 7–6 is closed, a current will flow in the loop. Since the loop is initially stationary, $e_{ind} = 0$. Therefore, the current will be given by

$$i = \frac{V_B - e_{\text{ind}}}{R} = \frac{V_B}{R}$$

This current flows through the rotor loop, producing a torque

$$\tau_{\text{ind}} = \frac{2}{\pi}\phi i \qquad \text{CCW}$$

This induced torque produces an angular acceleration in a counterclockwise direction, so the rotor of the machine begins to turn. But as the rotor begins to turn, an induced voltage is produced in the motor, given by

$$e_{\text{ind}} = \frac{2}{\pi}\phi\omega_m$$

so the current i falls. As the current falls, $\tau_{\text{ind}} = (2/\pi)\phi i\downarrow$ decreases, and the machine winds up in steady state with $\tau_{\text{ind}} = 0$, and the battery voltage $V_B = e_{\text{ind}}$.

This is the same sort of starting behavior seen earlier in the linear dc machine.

(b) At *starting conditions*, the machine's current is

$$i = \frac{V_B}{R} = \frac{120\ \text{V}}{0.3\ \Omega} = 400\ \text{A}$$

At *no-load steady-state conditions*, the induced torque τ_{ind} must be zero. But $\tau_{\text{ind}} = 0$ implies that current i must equal zero, since $\tau_{\text{ind}} = (2/\pi)\phi i$, and the flux is nonzero. The fact that $i = 0$ A means that the battery voltage $V_B = e_{\text{ind}}$. Therefore, the speed of the rotor is

$$V_B = e_{\text{ind}} = \frac{2}{\pi}\phi\omega_m$$

$$\omega = \frac{V_B}{(2/\pi)\phi} = \frac{V_B}{2rlB}$$

T = Wb/m

$$= \frac{120\ \text{V}}{2(0.5\ \text{m})(1.0\ \text{m})(0.25\ \text{T})} = 480\ \text{rad/s}$$

(c) If a load torque of 10 N • m is applied to the shaft of the machine, it will begin to slow down. But as ω decreases, $e_{ind} = (2/\pi)\phi\,\omega\downarrow$ decreases and the rotor current increases [$i = (V_B - e_{ind}\downarrow)/R$]. As the rotor current increases, $|\tau_{ind}|$ increases too, until $|\tau_{ind}| = |\tau_{load}|$ at a lower speed ω.

At steady state, $|\tau_{load}| = |\tau_{ind}| = (2/\pi)\phi i$. Therefore,

$$i = \frac{\tau_{ind}}{(2/\pi)\phi} = \frac{\tau_{ind}}{2rlB}$$

$$= \frac{10 \text{ N} \cdot \text{m}}{(2)(0.5 \text{ m})(1.0 \text{ m})(0.25 \text{ T})} = 40 \text{ A}$$

By Kirchhoff's voltage law, $e_{ind} = V_B - iR$, so

$$e_{ind} = 120 \text{ V} - (40 \text{ A})(0.3\ \Omega) = 108 \text{ V}$$

Finally, the speed of the shaft is

$$\omega = \frac{e_{ind}}{(2/\pi)\phi} = \frac{e_{ind}}{2rlB}$$

$$= \frac{108 \text{ V}}{(2)(0.5 \text{ m})(1.0 \text{ m})(0.25 \text{ T})} = 432 \text{ rad/s}$$

The power supplied to the shaft is

$$P = \tau\omega_m$$

$$= (10 \text{ N} \cdot \text{m})(432 \text{ rad/s}) = 4320 \text{ W}$$

The power out of the battery is

$$P = V_B i = (120 \text{ V})(40 \text{ A}) = 4800 \text{ W}$$

This machine is operating as a *motor,* converting electric power to mechanical power.

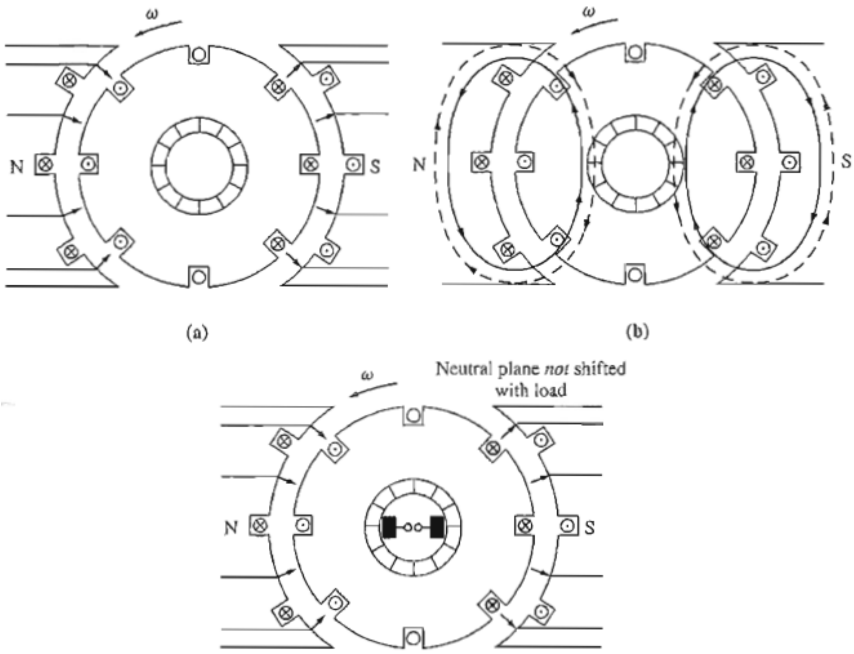
---

[c]:

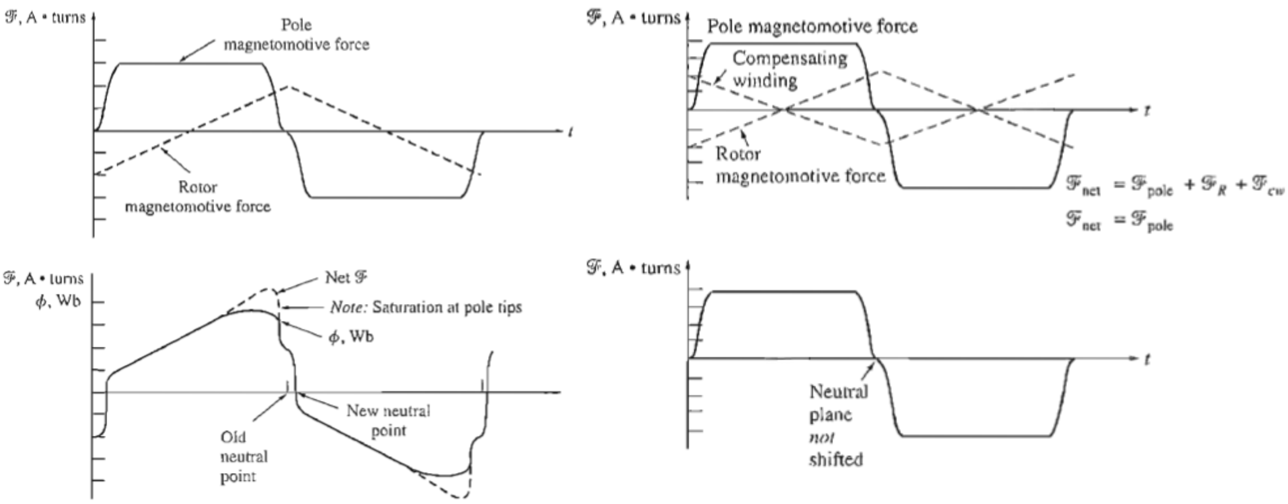
To completely cancel armature reaction and thus eliminate both neutral-plane shift and flux weakening, compensating windings are used. *This* involves placing *compensating windings* in slots carved in the faces of the poles parallel to the rotor conductors, to cancel the distorting effect of armature reaction. These windings are connected in series with the rotor windings, so that whenever the load changes in the rotor, the current in the compensating windings changes, too. The magnetomotive force due to the compensating windings is equal and opposite to the magnetomotive force due to the rotor at every point under the pole faces. The resulting net magnetomotive force is just

the magnetomotive force due to the poles, so the flux in the machine is unchanged regard less of the load on the machine. The major disadvantage of compensating windings is that they are expensive, since they must be machined into the faces of the poles. Any motor that uses them must also have interpoles, since compensating windings do not cancel *L dildt* effects. The in terpoles do not have to be as strong, though, since they are canceling only *L di/clt* voltages in the windings. and not the voltages due to neutral-plane shifting. Becallse of the expense of having both compensating windings and interpoles on such a machine, these windings are used only where the extremely severe nature of a motor's duty demands them.

i. Configuration:



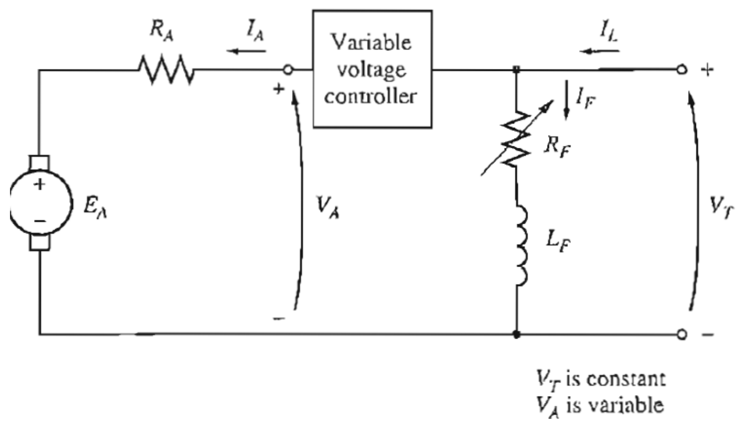
ii. flux and magnetomotive forces



Without compensating windings

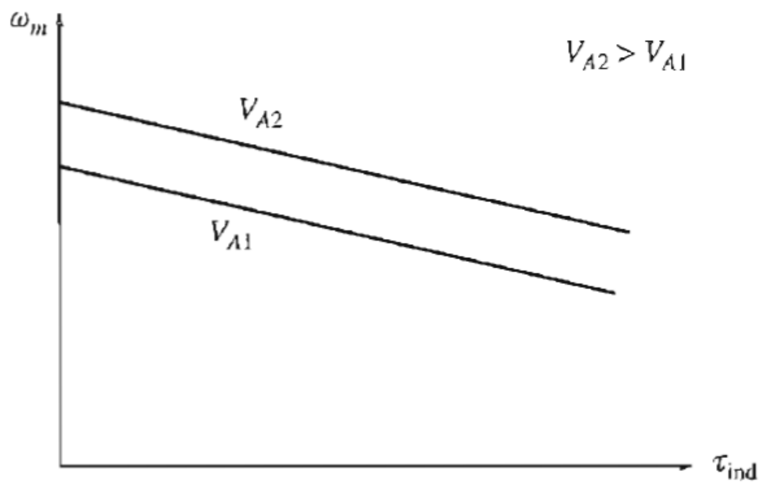
With compensating windings

[d]



$$\boxed{\omega_m = \frac{V_T}{K\phi} - \frac{R_A}{(K\phi)^2}\tau_{\text{ind}}}$$

1. An increase in V_A increases I_A [$= (V_A \uparrow - E_A)/R_A$].
2. Increasing I_A increases τ_{ind} ($= K\phi I_A\uparrow$).
3. Increasing τ_{ind} makes $\tau_{\text{ind}} > \tau_{\text{load}}$ increasing ω_m.
4. Increasing ω_m increases E_A($= K\phi\omega_m\uparrow$).
5. Increasing E_A decreases I_A [$= (V_A \uparrow - E_A)/R_A$].
6. Decreasing I_A decreases τ_{ind} until $\tau_{\text{ind}} = \tau_{\text{load}}$ at a higher ω_m.



Final-Term Exam 2014/2015		
2^{nd} Year: Electrical Power and Machines Engineering	Time: 3 hours	Mark: 120
		Code: EPM2208
2^{nd} Term: June , 2015	Course: Electric Machines (1)	

يرجى قراءة التعليمات التالية بعناية

- يقع هذا الإختبار فى عدد 3 صفحات وبه 4 اسئلة تقابل 120 درجة.
- تقع مسئولية التأكد من الحصول على كافة اوراق الأسئلة على الطالب
- برجاء كتابة تفاصيل العمليات التى تجريها. يحتفظ المصححون بحقهم فى خصم بعض الدرجات إذا لم نستطيع تحديد كيفية التوصل للنتائج (حتى لو كانت النتائج النهائية صحيحة).
- يجب مراعاة ان لا تحتوى الصفحة الواحدة على جزئيات تنتمى لأكثر من سؤال.
- ادعم إجاباتك بالمعادلات و الرسومات البيانية بقدر الإمكان.
- ضع خطين اسفل الإجابات النهائية لكل جزئية.

مع اطيب التمنيات

Question 1

[30 Marks]

[a] Draw the laboratory circuit connection(s), with suitable measurements instruments, and the equivalent circuit that is used to determine the external characteristics of shunt generator. Define all used symbols. Suggest a table of results. Draw the relevant characteristic(s). Write the necessary equations that are used. [10 Marks]

[b] Numerate the conditions of successful voltage build up of DC generator. [3 Marks]

[c] What are the factors affecting the quality of commutation process? [3Marks]

[d] Specify the conditions of parallel operation of DC generator. [4 Marks]

[e] What is the effect of brush shifting on the magnetic flux distribution? [4 Marks]

[f] Explain the function of the following: [6Marks]

[1] interlopes [2]compensating windings [3] Equalizing rings

Question 2

[3*10 = 30 Marks]

[a] A 4-poles DC generator with simple 2-layer lap winding with 16 armature coils, Determine:

[1] Number of commutator segments

[2] Front pitch, back pitch and commutator pitch.-

[3] Draw the development winding and show the brush position.

[b] Two shunt generators operate in parallel and their load-characteristics may be taken as straight lines. The first generator is rated 50 kW and 500 Volt. Its full load voltage regulation is 6%. The second generator is rated 100kW and 500 Volt. Its full load voltage regulation is 4%. Find the load current of each generator and the terminal voltage if they fed a load of 250A.

The voltage of first generator falls from 240V at no load to 220V at 200A, while that of second generator falls from 245V at no load to 220V at 150A. Determine the currents supplied by each machine to a common load of 300A and the bus-bar voltage.

[c] A dc compound generator is supplying a load of 100A at 220V. The resistances of its armature, shunt and series windings are 0.1Ω, 50Ω and 0.06Ω respectively. Find the induced EMF and the armature current when the machine is connected as a long shunt. How will the ampere turns of series windings would be changed, if a divertor of 0.14Ω is connected in parallel with the series windings?

Question 3 **[25 Marks]**

[a] Explain, with the aid of equation(s) and figure(s), the speed control of a shunt dc motor using changing the field resistance. [5 Marks]

[b] Can you operate a series excited dc motor at no-load (without being coupled to a mechanical load)?

No

[illegible]

With the aid of equations and figures, give reason for your answer. [5 Marks]

[c] A 10-hp 120-V 1000 r/min shunt dc motor has a full-load armature current of 70 A when operating at rated conditions. The armature resistance of the motor is $R_A = 0.12\ \Omega$, and the field resistance R_F is 40 Ω. The adjustable resistance in the field circuit R_{adj} may be varied over the range from 0 to 200 Ω and is currently set to 100 Ω. Armature reaction may be ignored in this machine. The magnetization curve for this motor, taken at a speed of 1000 r/min, is given in tabular form below:

E_A, V	5	78	95	112	118	126	130
I_F, A	0.00	0.80	1.00	1.28	1.44	2.88	4.00

i. What is the speed of this motor when it is running at the rated conditions specified above?

ii. The output power from the motor is 10 hp at rated conditions. What is the output torque of the motor?

iii. What are the copper losses and rotational losses in the motor at full load (ignore stray losses)?

iv. What is the efficiency of the motor at full load?

v. If the motor is now unloaded with no changes in terminal voltage or R_{adj}, what is the no-load speed of the motor?

vi. Suppose that the motor is running at the no-load conditions described in part (v). What would happen to the motor if its field circuit were to open? Ignoring armature reaction, what would the final steady-state speed of the motor be under those conditions?

vii. What range of no-load speeds is possible in this motor, given the range of field resistance adjustments available with R_{adj}? [15 Marks]

[35 Marks]

Question 4

a] Explain a solid-state motor drive system for armature voltage control. What are the advantages and disadvantages of solid-state motor drives compared to the Ward-Leonard system? Explain the possible modes of operation of the dc machine this driver. [10 Marks]

A 100-hp, 250-V, 350-A shunt dc motor with an armature resistance of 0.05 Ω. We wish to design a starter circuit for this motor which will limit the maximum starting current to twice its rated value and which will switch out sections of resistance as the armature current falls to its rated value. (i) How many stages of starting resistance will be required to limit the current to the range specified? (ii) What must the value of each segment of the resistor be? At what voltage should each stage of the starting resistance be cut out?

[10 Marks]

] A 100 Kw, 500 V, 6 pole, 450 rpm, dc shunt motor has the following data:

Armature diameter, D = 54 cm; Armature core length, L = 24.5 cm; Average flux density i the gap = 0.55 Web/m2. Find the number of armature slots and work out the details of suitable armature winding. Also, work out the dimensions of the slot. Assume the full loa efficiency of 0.89, an armature voltage drop of 5% of rated voltage, the field current 1 % line current, slot loading does not exceed 1500 AC, commentator diameter is 0.7 of co diameter, the height of a rectangular wire is taken as 17 mm, and current density conductor is 4.7 A/mm2. [15 Mark

With Best Regards

Dr. Mohamed El-Nemr

Dr. Abdelsalam Ahmed

$\frac{VT}{I_{mx}}$

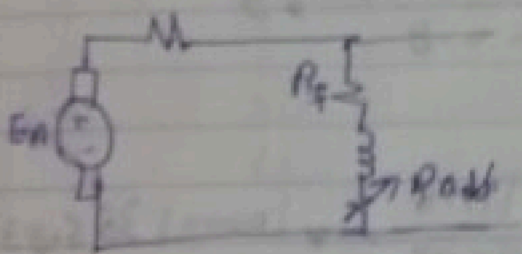
$R_2 + R_1 + RA = \frac{VT - EA}{I_{mx}}$

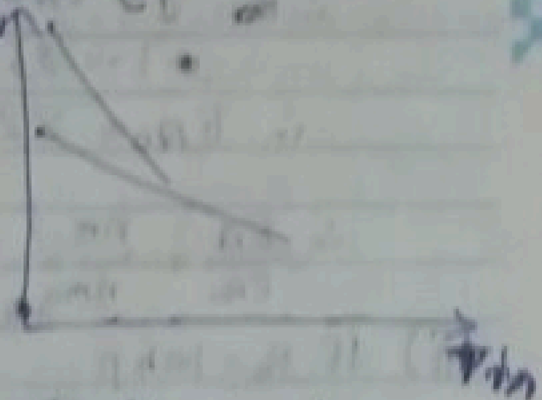
$VT - IA\,R_{tot}$

Q3 :-

a

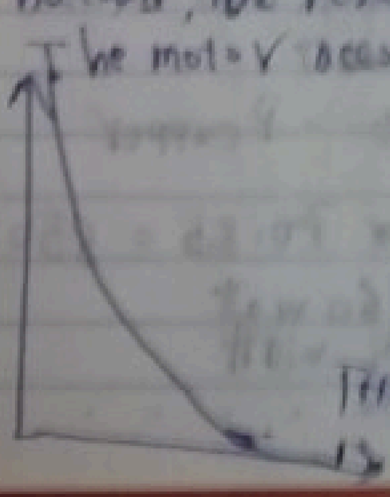
1- when The Field Resistance increases i_F decreases ($\downarrow i_F = \frac{V_T}{R_F \uparrow}$)
2- when i_F decreases Φ decreases
3- when Φ decreases E_A decreases ($\downarrow E_A = K\Phi\omega_m$)
4- When E_A decreases I_A increases ($\uparrow I_A = \frac{V_T - \downarrow E_A}{R_A}$)
5- When I_A increases T_{in} increases with the increase in I_A is the predominant effect over The decrease of Φ ($T_{in} = K\Phi I_A$)
6- when T_{in} increases, it exceeds T_L so w_m will increase
7- when $w_m \uparrow$, $E_A \uparrow$ ($\uparrow E_A = K\Phi w_m \uparrow$)
8- when $E_A \uparrow$, $I_A \downarrow$
9- when $I_A \downarrow$, $T_{in} \downarrow$ so w_m decreases till reaching T_L at steady state with higher w_m





b No, The series motor overspeeds at no load. When T_{in} Reaches (goes to zero), w_m goes to infinity, practically. T_{in} can't go to zero due to The mechanical, core and stray losses however, at no load, the resulted speed is too high to damage The motor according to The motor's chics.

$$w_m = \frac{V_T}{\sqrt{K_c}\sqrt{T_{in}}} - \frac{R_A + R_S}{K_c}$$



C

$P_o = 10\ hp$, shunt

$V_T = 120\ V$

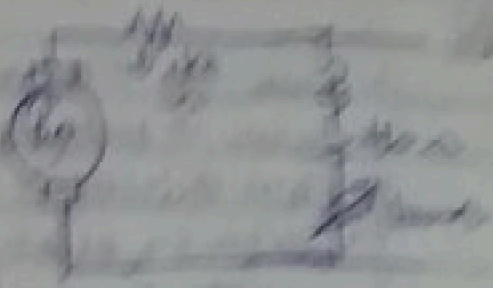
$n = 1000\ rpm$

$I_{A,\ rated} = 70\ A$

$R_A = 0.12\ \Omega$

$R_F = 40\ \Omega$

$R_{add} \Rightarrow 0 \to 200$ set at $100\ \Omega$



(i) At rated conditions, $I_A = 70\ A$

$\therefore E_A = 120 - 70 \times 0.12 = 111.6\ V$

$I_F = \frac{V_T}{R_F + R_{add}} = \frac{120}{140} = 0.85\ A$

$\therefore \frac{85 - E_{A0}}{1 - 0.85} = \frac{85 - 78}{1 - 0.9} = 85$

$\therefore E_{A0} = 82.25$ Volt

$\therefore \frac{E_A}{E_{A0}} = \frac{n_m}{n_{m0}} \Rightarrow n_m = \frac{111.6}{82.25} \times 1000 = 1356.83\ rpm$

(ii) If $P_o = 10\ hp$

$\tau_{out} = \frac{P_o}{\omega_m} = \frac{10 \times 746}{\frac{2\pi}{60} \times 1356.83}$

$= 52.5\ N.m$

(iii) $P_{copper} = I_A^2 R_A + I_F^2 (R_F + R_{add})$

$= (70)^2 \times (0.12) + (0.85)^2 \times (140)$

$= 683.15$ watt

$\therefore P_{rot} = P_{in} - P_{out} - P_{copper}$

$P_{in} = V_T I_L = 120 \times 70.85 = 8502$ watt

$\because P_{out} = 10\ hp = 7460$ watt

$\therefore P_{rot} = 352.85$ watt

(iv) $\eta = \frac{P_o}{P_{in}} * 100\% = \frac{7460}{8502} * 100\%$

$= 87.74\%$

(v) At no load, $V_T = E_A = 120V$

$i_F = 0.85 \Rightarrow E_{A0} = 82.25\ V$

$\therefore n_m = \frac{120}{82.25} * 1000 = 1458.96\ rpm$

(vi) when the field circuit is opened, the flux will drop drastically and hence, the E_A will decrease causing enormous increase in I_A, increase T_{in}. The increasing T_{in} now is higher a bit than T_L so the motor's speed increase and just keeps going up.

$E_A = V_T = 120V$

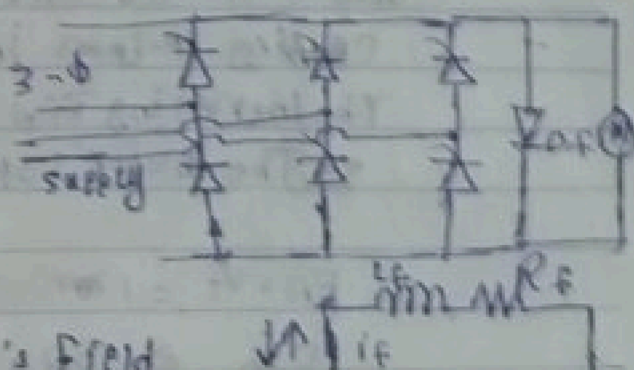
$I_F = 0 \Rightarrow E_{A0} = 5\ V$

$\therefore n_m = \frac{120}{5} * 1000 = 24,000\ rpm$

Q4:-

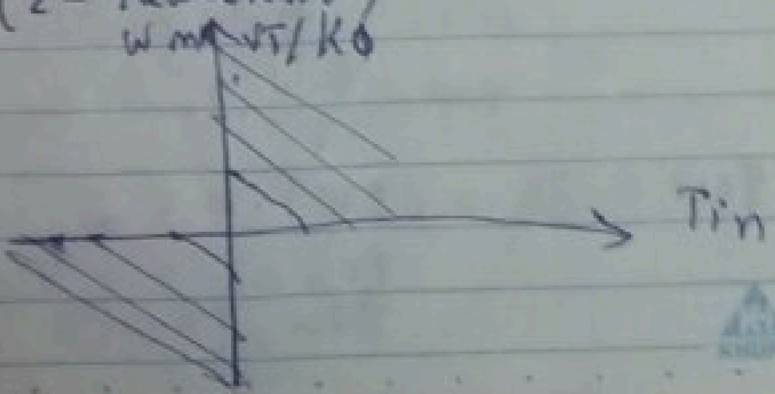
(a) In the solid state system, The average voltage applied to The motor, and hence the speed of The motor depends on The fraction time in which The supply is applied to The motor and this depends on The relative phase in which The thyristor circuits are triggered.

⇒ Two quandrant solid-state drive system

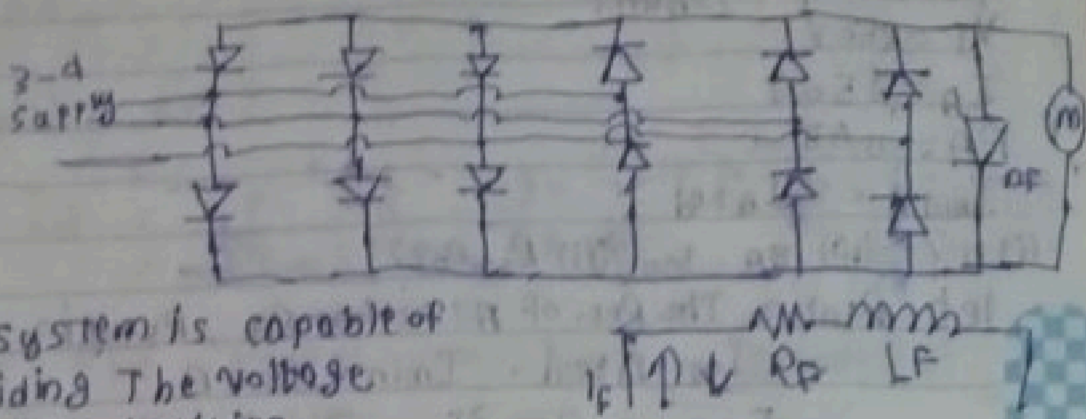


- This circuit can only provide The voltage in one polarity, so there's only one way to reverse The direction of The motor (By reversing The motor's field current)
- This system can't regenerate The motor's Energy of The motion back to The power lines since The current can't flow back from The positive terminals of The motor. (can't flow back from The tyristors)

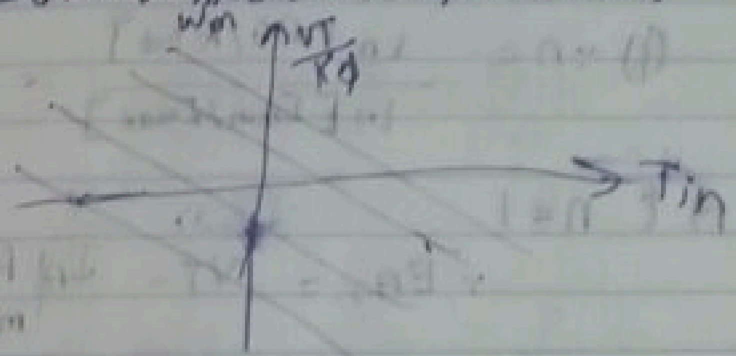
- So this system has two modes of operation (2-quandrant)



⇛ 4-quandrant solid-state system



1. This system is capable of providing The voltage in both polarities
- it can regenerate The motor's energy of The motion back To the power lines
- It has 4-quadrant modes of operation



Advantage of solid state motor drives over word leonord system:-

1. higher efficiency
2. cheeper since it uses only one drive instead of 3

b

$P_o = 100 hp$
$V_T = 250 V$, shunt
$I_A = 350 A$
$R_A = 0.05 \Omega$
$I_{max} = 2 I_{rated}$
i) n? (ii) E_{A} .. E_{An} ? (iii) R_1 .. R_n ??

let R_{tot} = The Res. of All sections + R_A , $R_{total,i} = R_{i+1} + .. + R_A$

$\because I_{A,rated} = I_{min} = 350 A$

$\because I_{max} = 2 * 350 = 700 A$

$$\therefore R_{tot} = \frac{250}{I_{max}} = \frac{250}{700} \simeq 0.357 \Omega$$

$$(i) \because n = \frac{\ln [R_A / R_{tot}]}{\ln [I_{min} / I_{max}]} = \frac{\ln\left(\frac{0.05}{0.357}\right)}{\ln\left(\frac{1}{2}\right)} \simeq 3 \text{ stages}$$

At n = 1

$$\because E_{A1} = V_T - I_{A\,min} R_{tot}$$

$$= 250 - (350)(0.357) = 125.05 V$$

$$\therefore R_{tot,1} = \frac{V_T - E_{A1}}{I_{max}} = \frac{250 - 125.05}{700}$$

$$= 0.1785 \Omega$$

At n = 2

$$\because E_{A2} = V_T - I_{min} * R_{tot,1}$$

$$= 250 - (350)(0.1785)$$

$$= 187.525 V$$

$$\therefore R_{tot,2} = \frac{250 - 187.525}{700} = 0.08925 \Omega$$

At n=3

$$E_{A3} = \frac{V_T - I_{min} * R_{tot,2}}{1} = 218.7625 V$$

$\because R_{total,3} = R_A = 0.05\ \Omega$

$$\therefore I_A = \frac{V_T - E_{A3}}{R_{tot,3}} = \frac{250 - 218.7625}{0.05} = 624.75 A < I_{max}$$

$\therefore R_1 = R_{tot} - R_{total,1} = 0.1785\ \Omega$, removed at E_{A1}

$\therefore R_2 = R_{total,1} - R_{tot,2} = 0.08925\ \Omega$, removed at E_{A2}

$\therefore R_3 = R_{tot,2} - R_{tot,3} = 0.03925\ \Omega$, removed at E_{A3}

[C] $P_o = 100\ kW$
$V_T = 500 V$
$2P = 6$ pole
$n = 450$ rpm

$$\because I_L = \frac{P_{in}}{V_T} = \frac{P_o}{\eta V_T} = \frac{100 * 10^3}{0.89 * 500} = 224.719 A$$

$\because I_A = I_L - I_F = 0.99\ I_L = 222.47 A$

$\because E_A = V_T - \Delta V = 0.95\ V_T = 475 V$

$\therefore P_d = 105.67 = C_o D^2 l n$

$$\therefore C_o = \frac{105.67}{(0.54)^2 * (0.245)(450)} = 3.2868$$

$\because C_o = 3.2868 = B * AC * 0.164 * 10^{-3}$

$$\therefore \overline{AC} = \frac{(0.164 * 10^{-3})^{-1}}{1} * \frac{3.2868}{0.55} = 36439.02\ \frac{AT}{m}$$

Assuming The motor is simplex lap (progressive)

$\therefore I_c = \frac{I_a}{2a} = \frac{222.47}{6} = 37.07 < 250\,A$

$\because \frac{Z}{2a} B l v_a = E_A$

$\therefore v_a = \frac{\pi D n}{60} = \frac{\pi}{60} * 450 * 0.54 = 12.72\, \frac{m}{s}$

$\therefore Z = \frac{E_A * 2a}{B l v_a} = \frac{475 * 6}{0.65 * 0.245 * 12.72}$

$= 1663$ conductors

Check $\Rightarrow A_c = \frac{Z I_c}{\pi D} = \frac{1663 * 37.07}{\pi * 0.54} = 36338$

$\because \frac{2.5}{100} \leq \lambda_s \leq \frac{3.5}{100} \Rightarrow 0.025 < \frac{\pi D}{S} \leq 0.035$

$\therefore 67 \geq S \geq 49$

$\because 9 \leq \frac{S}{2P} \leq 16 \Rightarrow 54 \leq S \leq 96$

$\because Z_s I_c \leq 1500 \Rightarrow \frac{Z}{S} I_c \leq 1500$

$S \geq 42$

Then $\Rightarrow 54 \leq S \leq 67$

$\because \frac{S}{2P}, \frac{S}{P} \Rightarrow$ must be integer

$\therefore S$ maybe $\Rightarrow 54$ or 60

$\frac{S}{2P} * \alpha \Rightarrow$ must be int $+ 0.5$

$S = 54$ slots

$\because Z_s = \frac{1663}{54} \approx 30 \Rightarrow Z = 1620$ conductors

$\because \frac{E_a \cdot 2a}{C} \leq 12 \Rightarrow C \geq 238$

$\because u = \frac{2C}{S} \Rightarrow$ must be even $\Rightarrow C = \frac{uS}{2}$

At $u = 10 \Rightarrow C = 270$ coils > 238

$\because \frac{Z_s}{u}$ must be 1 or even

$\therefore \frac{30}{10} = 3$ Refused

At $u = 30 \Rightarrow C = 810$ coils $\Rightarrow \frac{Z_s}{u} = 1$

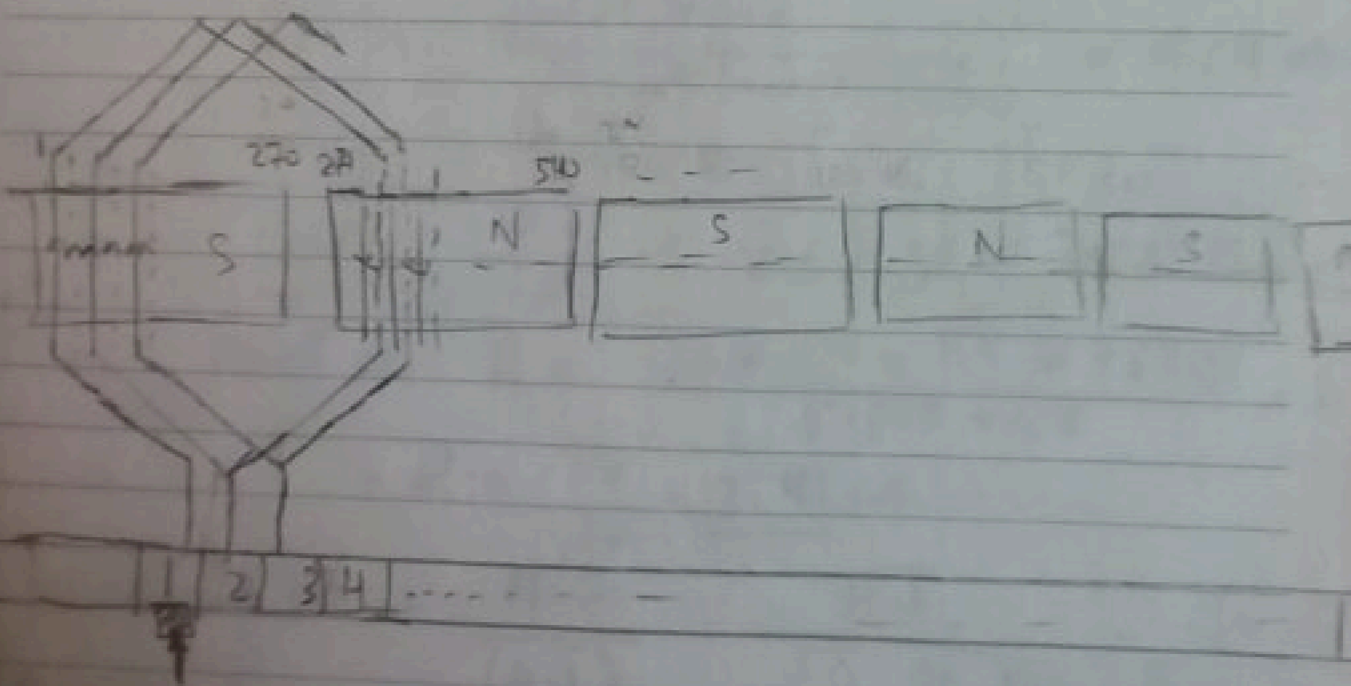
$N_c = 1$ turns

$\therefore$ The Armature design:-

$Z = 1620$, $C = 810$, $N_c = 1$, $S = 54$

Winding Diagram:-

- let The coil 1 is connected to seg 1
- Assuming The polarity



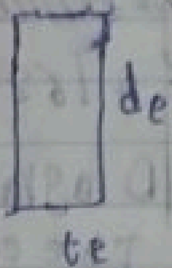
$x_B = 271$	$x_F = 269$	x_{c+1}
$1 \rightarrow 272$	$272 \rightarrow 3$	2
$3 \rightarrow 274$	$274 \rightarrow 5$	3
$5 \rightarrow 276$	$276 \rightarrow 7$	4
$7 \rightarrow 278$	$278 \rightarrow 9$	5
—	—	-
—	—	-

$\because I_c = 37.07\,A$

$\because a_c = \dfrac{I_c}{\delta_c} = \dfrac{37.07}{4.7} = 7.8\,mm^2$

$\because d_e = 17\,mm$

$\therefore t_e = \dfrac{7.8\,mm^2}{17\,mm} = 0.45\,mm$



Tanta University
Faculty of Engineering
Electrical Power and Machines Engineering Dept.

Final Exam – Second Semester 2015-2016

Course: EPM2208 (Electric Machines-1)	**Time allowed:** 3 hours
Year: 2nd Electrical Power and Machines Engineering	**Date:** 28 / 5 / 2016 (Saturday)
No. of Pages: 4	**Total Score:** 120

Remarks: Attempt to solve all of the following questions

يرجى قراءة التعليمات التالية بعناية

- يقع هذا الاختبار في عدد 4 صفحات وبه 6 اسئلة تقابل 120 درجة.
- **تقع مسئولية التأكد من الحصول على كافة اوراق الأسئلة على الطلب.**
- يرجاء كتابة تفاصيل العمليات التي تجريها. يحتفظ المصححون بحقهم في خصم بعض الدرجات إذا لم نستطيع تحديد كيفية التوصل للنتائج (حتى لو كانت النتائج النهائية صحيحة). ويلزم كتابة المعادلات بالرموز حسب المحاضرات قبل التعويض فيها.
- يجب مراعاة ان لا تحتوي الصفحة الواحدة على جزئيات تنتمي لأكثر من سؤال.
- دعم إجابتك بالمعادلات والرسومات البيانية بقدر الإمكان.
- ضع خطين أسفل الإجابات النهائية لكل جزئية.

Question - 1

20 points

[A] Draw the laboratory circuit connection(s), with suitable measurements instruments, and the equivalent circuit that is used to determine the no load characteristics of shunt generator. Define all used symbols. Suggest a table of results. Draw the relevant characteristic(s). Write the necessary equations that are used.

[B] The magnetization characteristic for a 4-pole, 110V, 1000 rpm shunt generator is as follows:

Field current (A)	0	0.5	1	1.5	2	2.5	3
O.C. voltage (V)	5	50	85	102	112	116	120

Armature is lap-connected with 144 conductors. Field resistance is 45Ω. Determine the following:

a) Voltage the machine will build up at no load
b) The critical resistance
c) The speed at which the machine just fails to excite
d) The residual flux per pole

Question - 2

20 points

[A] Specify the conditions of parallel operation of DC generator.

[B] Two shunt generators operate in parallel and their load-characteristics may be taken as straight lines. The voltage of first generator falls from 240V at no load to 220V at 200A, while that of second generator falls from 245V at no load to 220V at 150A. Determine the currents supplied by each machine to a common load of 300A and the bus-bar voltage.

[C] A long shunt generator running at 1000rpm supplies 20kW at terminal voltage of 220V. the resistance of armature, shunt and series field resistances are 0.04 Ω, 110 Ω and 0.05 Ω respectively. Overall efficiency at the above load is 85%. Find: (i) Copper loss, (ii) Iron and friction losses, and (iii) Torque developed by the prime mover.

Question 3

	20 Points (10+10)

[A] Choose the correct answer for the following statements: ***(Verification of your choice is A MUST when numerical data are given)***

(1) In a dc-shunt motor, the terminal voltage is halved while the torque is kept constant. The resulting approximate variation in speed 'ω_m' and armature current 'I_a' will be

(a) Both ω_m and I_a are doubled.

(b) ω_m is constant and I_a is doubled.

(c) ω_m is doubled while I_a is halved.

(d) ω_m is constant but I_a is halved.

(2) A 4-pole lap wound dc-shunt motor rotates at the speed of 1500 rpm, has a flux of 0.4mWb and the total number of conductors are 1000. What is the value of the back *emf* ?

(a) 100 Volts. (b) 0.1 Volts. (c) 1 Volts. (d) 10 Volts.

(3) A dc-shunt motor runs at no load speed of 1140 rpm. At full load, armature reaction weakens the main flux by 5% whereas the armature circuit voltage drops by 10%. The motor full load speed in rpm is

(a) 1080 (b) 1203 (c) 1000 (d) 1200

(4) As compared to shunt and compound dc motors, the series dc motor will have the highest torque because of its comparatively __________ at the start.

(a) Lower armature resistance.

(b) Stronger series field.

(c) Fewer series turns.

(d) Larger armature current.

(5) Regenerative braking

(a) Can be used for stopping a motor.

(b) Cannot be easily applied to dc series motors.

(c) Can be easily applied to dc shunt motors

(d) Cannot be used when motor load has overhauling characteristics.

(6) If field current is decreased in shunt dc motor, the speed of the motor

(a) remains same (b) increases (c) decreases (d) none of these

(7) Ward-Leonard control is basically a __________ control method.

(a) field (b) armature resistance (c) armature voltage control (d) field divertor

(8) For very sensitive and wide speed control, the preferable control method is ____ control

(a) armature voltage (b) field (c) armature resistance (d) Word-Leonard

(9) Maximum power will be developed when back ems is __________

(a) equals to supply voltage

(b) half of the supply voltage

(c) doubles the supply voltage

(d) all of the above

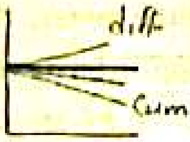
(10) Which motor cannot be started on no load?

(a) shunt motors (b) series motors (c) cumulative compound (d) both (b) and (c)

[B] State true (√) or false (×) and correct the false statements

ملاحظة هامة: في حالة وضع علامة x يجب تصحيح الفقرة وإلا فلن يلتفت الى الاجابة

(1) Cumulative compound motors can have a negative speed regulation.



(2) Field weakening control method can be used for the above rated speeds.

(3) Armature resistance control method is used for the below rated speeds.

(4) If the terminal voltage of one 1000 rpm shunt motor is reduced by 50% of the rated value, then the motor speed will be 500 rpm.

$T_f \quad \varphi_1 = \frac{\varphi}{2}$

(5) The direction of rotation of a dc series motor can be changed by interchanging the supply voltage.

(6) The increase in the torque expressed as a percentage of an initial torque is 11%, if the current drawn by the dc-series motor is increased from 10A to 11A.

$T_f \downarrow \quad \varphi \downarrow \quad \omega_m \uparrow$

(7) In armature voltage control for speed control in dc-shunt motor, a variable resistance is added in series with the field winding.

(8) In the flux control method for controlling the speed of dc-shunt motors, the speed is not possible above normal rated speed.

(9) If a portion of armature current is diverted through the diverter resistance, then the speed of dc-series motor decreases.

(10) The torque in a differential compound motor decrease with an increase in the armature current.

Question 4

20 Points (5,15)

[A] What is the plugging? Why is it necessary to insert a resistance in the armature circuit when plugging a motor? When a plugged motor attains zero speed, what is the current in the armature?

[B] A 120-V, 2400-rpm shunt motor has an armature resistance of 0.4 Ω and a shunt field resistance of 160 Ω. The motor operates at its rated speed at full-load and takes 14.75 A. The no-load current is 2 A. When an external resistance of 3.6 Ω is inserted in the armature circuit with no change in the torque developed, calculate:

(i) The motor speed, the power loss in the external resistance, and the efficiency of the motor. Assume that the rotational loss is proportional to the speed.

(ii) If an external resistance of 80 Ω is inserted in series with the shunt field winding instead of the armature circuit. Determine the motor speed, the power loss in the external resistance, and the efficiency of the motor. Assume that the flux is proportional to the square root of the field-winding current and the motor develops the same torque.

Question 5	22 Points (12,10)
[A]	A shunt coil of a dc machine has to develop an mmf of 9000 ampere-turns. The voltage drop across the coil is 40 V, and the resistivity of wire used is 0.021 micro ohm-meter. The depth of the coil is 0.035 m approximately and the mean length of one turn is 1.4 m approximately. Design the coil so that the permissible loss is 700 W per square meter of the inner and outer surfaces. Neglect the cooling surface at both coil ends and assume a space factor of 0.606 to determine (a) number of turns per layer and number of layers (b) final dimensions of the coil width and height.
[B]	(i) Draw the electric circuit that is analogous to the magnetic circuit between two adjacent poles of dc machines. (ii) Sketch three different paths for the leakage flux of armature winding of dc machines and name them. (iii) State two different constrains on the interpole circumference width $1.53 < W_{ip} < \frac{1-\alpha}{2}\tau_p$ (iv) State a range for the slot pitch in dc machines whose output power is of the order of 500 kW.

Question 6	18 Points

A 500 V, 300 rpm, 14 poles, simple lap connected armature winding dc shunt motor with compensating *windings and interpoles has the following particulars:*

547 single turn coils; pole arc to pole pitch ratio = commutator diameter to armature diameter ratio = 0.7; specific electric loading = 39152 AC/m; armature diameter = 2 m; mmf required for the iron parts of the interpole = 20 % of that required for the air gap under it; ampere turns of the interpole coil = 5800; width of the commutating zone referred to the commutator = 0.0367 m; armature core axial length = 0.28 m; flux density under each interpole = 0.3 T; interpole axial length = 0.16 m; radial height of the main pole = 0.2 m.

Find:

(i)	effective air gap length under each interpole
(ii)	time of commutation
(iii)	average reactive voltage in the coil undergoing commutation
(iv)	brushes area per brush spindle assuming a current density of 70000 A/squared meter and neglecting the field current
(v)	radial depth of each commutator segment
(vi)	Specific magnetic loading in tesla.

Wish you all the best

Prof. Ahmed Shobair, Dr. Mohamed El-Nemr and

Dr. Sherif Dabour

Question (6) Exam 2016

Given: 500V, 300 rpm, 14 poles, simple-lap, Comp. winding and interpoles dc motor

$C = 547$, $N_c = 1$, $\alpha = 0.7$, $\frac{D_c}{D} = 0.7$,

$\overline{AC} = 39152$ AC/m, $D = 2$ m,

$AT_{iron_i} = 20\% \, AT_{gi}$, $AT_i = 5800$

$w_c = 0.0367$ m, $L = 0.28$ m, $B_{gi} = 0.3T$

$l_{pi} = 0.16$ m, $h_p = 0.2$ m, $\delta_b = 70000$ A/m^2

Req: (i) l_{gi} (ii) T_c (iii) E_{gi} (iv) ab

(v) h_c (vi) B_{av}

Sol:

(i) $AT_i = AT_{gi} + AT_{iron_i} + AT_a$

$$AT_i = 1.2 \, AT_{gi} + AT_a$$

$$AT_a \Big]_{\text{with Comp.W.}} = (1-\alpha) \frac{I_c Z}{2(2p)}$$

$$\overline{AC} = \frac{I_c Z}{\pi D} \Rightarrow I_c Z = \pi D \overline{AC}$$

$$AT_a = (1-\alpha) \frac{\pi D \overline{AC}}{2(2p)} = (1-0.7) \frac{\pi * 2 * 39152}{2 * 14}$$

$$= 2636 \text{ AT}$$

$$\therefore 5800 = 1.2 \, AT_{gi} + 2636$$

$$AT_{g_i} = \frac{5800 - 2636}{1.2} = 2636 \text{ A.Turn}$$

$$AT_{gi} = 800\,000 \; B_{gi} \; \cancel{k_{gi}} \; l_{gi}$$

$$2636 = 800\,000 * 0.3 * 1 * l_{gi}$$

$$\boxed{l_{gi} = 0.011 \text{ m}} \; \#$$

(ii) $$v_c = \frac{\pi D_a n}{60} = \frac{\pi * 2 * 300}{60} = 31.4 \text{ m/s}$$

$$T_c = \frac{w_c}{v_c} = \frac{0.0367}{31.4} = \boxed{1.168 \text{ mS}} \; \#$$

(iii) $$E_{gi} = 2 \, N_c \, B_{gi} \, L v_c$$

$$= 2 * 1 * 0.3 * 0.28 * 31.4$$

$$= \boxed{5.3\text{V}} \; \#$$

(iv) $$\overline{AC} = \frac{I_c Z}{\pi D} = 39152$$

$$Z = 2 N_c C = 2 * 1 * 547 = 1094 \text{ Conductors}$$

$$I_c = \frac{\pi D \overline{AC}}{Z} = \frac{\pi * 2 * 39152}{1094} = 224.86 \text{ A}$$

For simplex lap: $I_a = (2a) * I_c = (2p) * I_c$

$$= 14 * 224.86 = 3148 \text{ A}$$

$$I_{spindle} = \frac{I_a}{p} = \frac{3148}{7} \simeq 450 \text{ A}$$

It is known that $I_b \leq 70A$

$$\therefore n_b = \frac{I_{spindle}}{I_b} = \frac{450}{70} = 6.4$$

Arbitrarily, let $n_b = 8$

$$\therefore I_b = \frac{450}{8} = 56.25 A$$

$$a_b = \frac{I_b}{\delta_b} = \frac{56.25}{70000} = 8.0357 * 10^{-4} \ m^2$$

$$= \boxed{803.57 \ mm^2} \ \#$$

(v) $h_c = \frac{D_c + 0.38}{15}$ for $v_c \leq 23$ m/s

$$D_c = 0.7 \times D = 0.7 * 2 = 1.4 \ m$$

$$h_c = \frac{1.4 + 0.38}{15} = 0.1187 \ m$$

~~However Since~~

$$v_c = \frac{\pi D_c n}{60} = \frac{\pi * 1.4 * 300}{60} = 22 \ m/s$$

(vi) Neglecting losses & field current, $P_d = V I_a = 500 * 3148 A$

$$= 1574 \ kW$$

$$P_d = C_o D^2 L n = 0.164 * 10^{-3} * B_{av} * \overline{AC} * D^2 * L * n$$

$$B_{av} = \frac{P_d \ 1574}{0.164 \times 10^{-3} * 39152 * (2)^2 * 0.28 * 300} = \boxed{0.7295 \ T} \ \#$$

specific magnetic loading